# Glossary of Vibration Terms

## A

**Acceleration —** The time rate of change of velocity. Typical units are ft/s/s, meters/s/s, and g's (1g = 32.17 ft/s/s = 9.81 m/s/s). Acceleration measurements are usually made with accelerometers.

**Accelerometer —**Transducer whose output is directly proportional to acceleration. Most commonly use piezoelectric crystals to produce output.

**Aliasing —** A phenomenon which can occur whenever a signal is not sampled at greater than twice the maximum frequency component. Causes high frequency signals to appear at low frequencies. Aliasing is avoided by filtering out signals greater than 1/2 the sample rate.

**Alignment —**A condition whereby the axes of machine components are either coincident, parallel or perpendicular, according to design requirements.

**Amplification Factor (Synchronous)**. A measure of the susceptibility of a rotor to vibration amplitude when rotational speed is equal to the rotor natural frequency (implies a flexible rotor). For imbalance type excitation, synchronous amplification factor is calculated by dividing the amplitude value at the resonant peak by the amplitude value at a speed well above resonance (as determined from a plot of synchronous response vs. rpm).

**Amplitude**. The magnitude of dynamic motion or vibration. Amplitude is expressed in terms of peak-to peak, zero-to-peak, or rms. For pure sine waves only, these are related as follows: rms = 0.707 times zero-to peak; peak-to-peak = 2 times zero-to-peak. DSAs generally read rms for spectral components, and peak for time domain components.

**Anti-Aliasing Filter**. A low-pass filter designed to filter out frequencies higher than 1/2 the sample rate in order to prevent aliasing.

**Anti-Friction Bearing**. See Rolling Element Bearing.

**Asymetrical Support**. Rotor support system that does not provide uniform restraint in all radial directions. This is typical for most heavy industrial machinery where stiffness in one plane may be substantially different than stiffness in the perpendicular plane. Occurs in bearings by design, or from preloads such as gravity or misalignment.

**Asynchronous**. Vibration components that are not related to rotating speed (also referred to as nonsynchronous).

**Attitude Angle** (Steady-State). The angle between the direction of steady-state preload through the bearing centerline, and a line drawn between the shaft centerline and the bearing centerline. (Applies to fluid film bearings.)

**Auto Spectrum** (Power Spectrum). DSA spectrum display whose magnitude represents the power at each frequency, and which has no phase. RMS averaging produces an auto spectrum.

**Averaging**. In a DSA, digitally averaging several measurements to improve accuracy or to reduce the level of asynchronous components. Refer to definitions of RMS, time, and peak-hold averaging.

**Axial**. In the same direction as the shaft centerline.

**Axial Position**. The average position, or change in position, of a rotor in the axial direction with respect to some fixed reference position. Ideally the reference is a known position within the thrust bearing axial clearance or float zone, and the measurement is made with a displacement transducer observing the thrust collar.

# B

**Balancing Resonance Speed(s)**. A rotative speed that corresponds to a natural resonance frequency. Balanced Condition. For rotating machinery, a condition where the shaft geometric centerline coincides with the mass centerline.

**Balancing**. A procedure for adjusting the radial mass distribution of a rotor so that the mass centerline approaches the rotor geometric centerline.

**Band-Pass Filter**. A filter with a single transmission band extending from lower to upper cutoff frequencies. The width of the band is determined by the separation of frequencies at which amplitude is attenuated by 3 dB (0.707).

**Bandwidth**. The spacing between frequencies at which a band-pass filter attenuates the signal by 3 dB. In a DSA, measurement bandwidth is equal to [(frequency span)/(number of filters) x (window factor)]. Window factors are: 1 for uniform , 1.5 for Hanning, and 3.63 for flat top.

**Baseline Spectrum**. A vibration spectrum taken when a machine is in good operating condition; used as a reference for monitoring and analysis.

**Blade Passing Frequency**. A potential vibration frequency on any bladed machine (turbine, axial compressor, fan, etc.). It is represented by the number of blades times shaft-rotating frequency.

**Block Size**. The number of samples used in a DSA to compute the Fast Fourier Transform. Also the number of samples in a DSA time display. Most DSAs use a block size of 1024. Smaller block size reduces resolution.

**Bode**. Rectangular coordinate plot of 1x component amplitude and phase (relative to a keyphasor) vs. running speed.

**BPFO, BPFI**. Common abbreviations for ball pass frequency of defects on outer and inner bearing races, respectively.

**Bow**. A shaft condition such that the geometric centerline of the shaft is not straight.

**Brinneling** (False). Impressions made by bearing rolling elements on the bearing race; typically caused by external vibration when the shaft is stationary.

# C

**Calibration**. A test during which known values of the measured variable are applied to the transducer or readout instrument, and output readings varied or adjusted.

**Campbell Diagram**. A mathematically constructed diagram used to check for coincidence of vibration sources (i.e. 1 x imbalance, 2 x misalignment) with rotor natural resonances. The form of the diagram is a

rectangular plot of resonant frequency (y-axis) vs excitation frequency (x-axis). Also known as an interference diagram.

**Cascade Plot**. See Spectral Map.

**Cavitation**. A condition which can occur in liquid handling machinery (e.g. centrifugal pumps) where a system pressure decrease in the suction line and pump inlet lowers fluid pressure and vaporization occurs. The result is mixed flow which may produce vibration.

**Center Frequency**. For a bandpass filter, the center of the transmission band.

**Charge Amplifier**. Amplifier used to convert accelerometer output impedance from high to low, making calibration much less dependent on cable capacitance.

**Coherence**. The ratio of coherent output power between channels in a dual-channel DSA. An effective means of determining the similarity of vibration at two locations, giving insight into the possibility of cause and effect relationships.

**Constant Bandwidth Filter**. A band-pass filter whose bandwidth is independent of center frequency. The filters simulated digitally in a DSA are constant band width.

**Constant Percentage Bandwidth**. A band-pass filter whose bandwidth is a constant percentage of center frequency. 1/3 octave filters, including those synthesized in DSAs, are constant percentage bandwidth.

**Critical Machinery**. Machines which are critical to a major part of the plant process. These machines are usually unspared.

**Critical Speeds**. In general, any rotating speed which is associated with high vibration amplitude. Often, the rotor speeds which correspond to natural frequencies of the system.

**Critical Speed Map**. A rectangular plot of system natural frequency (y-axis) versus bearing or support stiffness (x-axis).

**Cross Axis Sensitivity**. A measure of off-axis response of velocity and acceleration transducers.

**Cycle**. One complete sequence of values of a periodic quantity.


# D

**Damping**. The quality of a mechanical system that restrains the amplitude of motion with each successive cycle. Damping of shaft motion is provided by oil in bearings, seals, etc. The damping process converts mechanical energy to other forms, usually heat.

**Damping, Critical**. The smallest amount of damping required to return the system to its equilibrium position without oscillation.

**Decibels** (dB). A logarithmic representation of amplitude ratio, defined as 20 times the base ten logarithm of the ratio of the measured amplitude to a reference. DbV readings, for example, are referenced to 1 volt rms. Db amplitude scales are required to display the full dynamic range of a DSA.

**Degrees Of Freedom**. A phrase used in mechanical vibration to describe the complexity of the system. The number of degrees of freedom is the number of independent variables describing the state of a vibrating system.

**Digital Filter**. A filter which acts on data after it has been sampled and digitized. Often used in DSAs to provide anti-aliasing protection after internal re-sampling.

**Differentiation**. Representation in terms of time rate of change. For example, differentiating velocity yields acceleration. In a DSA, differentiation is performed by multiplication by jw, where w is frequency multiplied by 2þ. (Differentiation can also be used to convert displacement to velocity.)

**Discrete Fourier Transform**. A procedure for calculating discrete frequency components (filters or lines) from sampled time data. Since the frequency domain result is complex (i.e., real and imaginary components), the number of points is equal to half the number of samples.

**Displacement**. The change in distance or position of an object relative to a reference.

**Displacement Transducer**. A transducer whose output is proportional to the distance between it and the measured object (usually the shaft).

**DSA**. See Dynamic Signal Analyzer.

**Dual Probe**. A transducer set consisting of displacement and velocity transducers. Combines measurement of shaft motion relative to the displacement transducer with velocity of the displacement transducer to produce absolute motion of the shaft.

**Dual Voting**. Concept where two independent inputs are required before action (usually machine shutdown is taken. Most often used with axial position measurements, where failure of a single transducer might lead to an unnecessary shutdown.

**Dynamic Motion**. Vibratory motion of a rotor system caused by mechanisms that are active only when the rotor is turning at speeds above slow roll speed.

**Dynamic Signal Analyzer (DSA)**. Vibration analyzer that uses digital signal processing and the Fast Fourier Transform to display vibration frequency components. DSAs also display the time domain and phase spectrum, and can usually be interfaced to a computer.

# E

**Eccentricity, Mechanical**. The variation of the outer diameter of a shaft surface when referenced to the true geometric centerline of the shaft. Out-of-roundness.

**Eccentricity Ratio**. The vector difference between the bearing centerline and the average steady-state journal centerline.

**Eddy Current**. Electrical current which is generated (and dissipated) in a conductive material in the presence of an electromagnetic field.

**Electrical Runout**. An error signal that occurs in eddy current displacement measurements when shaft surface conductivity varies.

**Engineering Units**. In a DSA, refers to units that are calibrated by the user (e.g., in/s, g's).

**External Sampling**. In a DSA, refers to control of data sampling by a multiplied tachometer signal. Provides a stationary display of vibration with changing speed.

# F

**Fast Fourier Transform (FFT)**. A computer (or microprocessor) procedure for calculating discrete frequency components from sampled time data. A special case of the discrete Fourier transform where the number of samples is constrained to a power of 2.

**Filter**. Electronic circuitry designed to pass or reject a specific frequency band.

**Finite Element Modeling**. A computer aided design technique for predicting the dynamic behavior of a mechanical system prior to construction. Modeling can be used, for example, to predict the natural frequencies of a flexible rotor.

**Flat Top Filter**. DSA window function which provides the best amplitude accuracy for measuring discrete frequency components.

**Fluid-Film Bearing**. A bearing which supports the shaft on a thin film of oil. The fluid-film layer may be generated by journal rotation (hydrodynamic bearing), or by externally applied pressure (hydrostatic bearing).

**Forced Vibration**. The oscillation of a system under the action of a forcing function. Typically forced vibration occurs at the frequency of the exciting force.

**Free Vibration**. Vibration of a mechanical system following an initial force—typically at one or more natural frequencies.

**Frequency**. The repetition rate of a periodic event, usually expressed in cycles per second (Hz), revolutions per minute (rpm), or multiples of a rotational speed (orders). Orders are commonly referred to as 1x for rotational speed, 2x for twice rotational speed, etc.

**Frequency Response**. The amplitude and phase response characteristics of a system.

# G

**G**. The value of acceleration produced by the force of gravity.

**Gear Mesh Frequency**. A potential vibration frequency on any machine that contains gears; equal to the number of teeth multiplied by the rotational frequency of the gear.

# H

**Hanning Window**. DSA window function that provides better frequency resolution than the flat top window, but with reduced amplitude accuracy.

**Harmonic**. Frequency component at a frequency that is an integer multiple of the fundamental frequency.

**Heavy Spot**. The angular location of the imbalance vector at a specific lateral location on a shaft. The heavy spot typically does not change with rotational speed.

**Hertz** (Hz). The unit of frequency represented by cycles per second.

**High Spot**. The angular location on the shaft directly under the vibration transducer at the point of closest proximity. The high spot can move with changes in shaft dynamics (e.g., from changes in speed).

**High-Pass Filter**. A filter with a transmission band starting at a lower cutoff frequency and extending to (theoretically) infinite frequency.

**Hysteresis**. Non-uniqueness in the relationship between two variables as a parameter increases or decreases. Also called deadband, or that portion of a system's response where a change in input does not produce a change in output.

# I

**Imbalance**. Unequal radial weight distribution on a rotor system; a shaft condition such that the mass and shaft geometric centerlines do not coincide.

**Impact Test**. Response test where the broad frequency range produced by an impact is used as the stimulus. Sometimes referred to as a bump test.

**Impedance, Mechanical**. The mechanical properties of a machine system (mass, stiffness, damping) that determine the response to periodic forcing functions.

**Influence Coefficients**. Mathematical coefficients that describe the influence of system loading on system deflection.

**Integration**. A process producing a result that, when differentiated, yields the original quantity. Integration of acceleration, for example, yields velocity. Integration is performed in a DSA by dividing by jw, where w is frequency multiplied by 2þ. (Integration is also used to convert velocity to displacement).

# J

**Journal**. Specific portions of the shaft surface from which rotor applied loads are transmitted to bearing supports.

# K

**Keyphasor**. A signal used in rotating machinery measurements, generated by a transducer observing a once-per-revolution event. The keyphasor signal is used in phase measurements for analysis and balancing. (Keyphasor is a Bently Nevada trade name.)

# L

**Lateral Location**. The definition of various points along the shaft axis of rotation.

**Lateral Vibration**. See Radial Vibration.

**Leakage**. In DSAs, a result of finite time record length that results in smearing of frequency components. Its effects are greatly reduced by the use of weighted window functions such as flat top and Hanning.

**Linearity**. The response characteristics of a linear system remain constant with input level. That is, if the response to input a is A, and the response to input b is B, then the response of a linear system to input (a + b) will be (A + B). An example of a non-linear system is one whose response is limited by mechanical stop, such as occurs when a bearing mount is loose.

**Lines**. Common term used to describe the filters of a DSA (e.g., 400 line analyzer).

**Linear Averaging**. See Time Averaging.

**Low-Pass Filter**. A filter whose transmission band extends from dc to an upper cutoff frequency.

# M

**Mechanical Runout**. An error in measuring the position of the shaft centerline with a displacement probe that is caused by out-of-roundness and surface imperfections.

**Micrometer (MICRON)**. One millionth (.000001) of a meter. (1 micron = 1 x E-6 meters = 0.04 mils.)

**MIL**. One thousandth (0.001) of an inch. (1 mil = 25.4 microns.)

**Modal Analysis**. The process of breaking complex vibration into its component modes of vibration, very much like frequency domain analysis breaks vibration down to component frequencies.

**Mode Shape**. The resultant deflected shape of a rotor at a specific rotational speed to an applied forcing function. A three-dimensional presentation of rotor lateral deflection along the shaft axis.

**Modulation, Amplitude (AM)**. The process where the amplitude of a signal is varied as a function of the instantaneous value of another signal. The first signal is called the carrier, and the second signal is called the modulating signal. Amplitude modulation produces a component at the carrier frequency, with adjacent components (sidebands) at the frequency of the modulating signal.

**Modulation, Frequency (FM)**. The process where the frequency of the carrier is determined by the amplitude of the modulating signal. Frequency modulation produces a component at the carrier frequency, with adjacent components (sidebands) at the frequency of the modulating signal.

# N

**Natural Frequency**. The frequency of free vibration of a system. The frequency at which an undamped system with a single degree of freedom will oscillate upon momentary displacement from its rest position.

**Nodal Point**. A point of minimum shaft deflection in a specific mode shape. May readily change location along the shaft axis due to changes in residual imbalance or other forcing function, or change in restraint such as increased bearing clearance.

**Noise**. Any component of a transducer output signal that does not represent the variable intended to be measured.

**Nyquist Criterion**. Requirement that a sampled system sample at a frequency greater than twice the highest frequency to be measured.

**Nyquist Plot**. A plot of real versus imaginary spectral components that is often used in servo analysis. Should not be confused with a polar plot of amplitude and phase of 1x vibration.

# O

**Octave**. The interval between two frequencies with a ratio of 2 to 1.

**Oil Whirl/Whip**. An unstable free vibration whereby a fluid-film bearing has insufficient unit loading. Under this condition, the shaft centerline dynamic motion is usually circular in the direction of rotation. Oil whirl occurs at the oil flow velocity within the bearing, usually 40 to 49% of shaft speed. Oil whip occurs when the whirl frequency coincide with (and becomes locked to) a shaft resonant frequency. (Oil whirl and whip can occur in any case where fluid is between two cylindrical surfaces. )

**Orbit**. The path of the shaft centerline motion during rotation. The orbit is observed with an oscilloscope connected to x and y-axis displacement transducers. Some dual-channel DSAs also have the ability to display orbits.

**Oscillator-Demodulator**. A signal conditioning device that sends a radio frequency signal to an eddy-current displacement probe, demodulates the probe output, and provides output signals proportional to both the average and dynamic gap distances. (Also referred to as Proximitor, a Bently Nevada trade name.)

# P – Q

**Peak Hold**. In a DSA, a type of averaging that holds the peak signal level for each frequency component.

**Period**. The time required for a complete oscillation or for a single cycle of events. The reciprocal of frequency.

**Phase.** A measurement of the timing relationship between two signals, or between a specific vibration event and a keyphasor pulse.

**Piezoelectric**. Any material which provides a conversion between mechanical and electrical energy. For a piezoelectric crystal, if mechanical stresses are applied on two opposite faces, electrical charges appear on some other pair of faces.

**Polar Plot**. Polar coordinate representation of the locus of the 1x vector at a specific lateral shaft location with the shaft rotational speed as a parameter.

**Power Spectrum**. See Auto Spectrum.

**Preload, Bearing**. The dimensionless quantity that is typically expressed as a number from zero to one where a preload of zero indicates no bearing load upon the shaft, and one indicates the maximum preload (i.e., line contact between shaft and bearing).

**Preload, External**. Any of several mechanisms that can externally load a bearing. This includes `soft" preloads such as process fluids or gravitational forces as well as "hard" preloads from gear contact forces, misalignment, rubs, etc.

# R

**Radial**. Direction perpendicular to the shaft centerline.

**Radial Position**. The average location, relative to the radial bearing centerline, of the shaft dynamic motion.

**Radial Vibration**. Shaft dynamic motion or casing vibration which is in a direction perpendicular to the shaft centerline.

**Real-Time Analyzer**. See Dynamic Signal Analyzer.

**Real-Time Rate**. For a DSA, the broadest frequency span at which data is sampled continuously. Real-time rate is mostly dependent on FFT processing speed.

**Rectangular Window**. See Uniform Window.

**Relative Motion**. Vibration measured relative to a chosen reference. Displacement transducers generally measure shaft motion relative to the transducer mounting.

**Repeatability**. The ability of a transducer or readout instrument to reproduce readings when the same input is applied repeatedly.

**Resolution**. The smallest change in stimulus that will produce a detectable change in the instrument output.

**Resonance**. The condition of vibration amplitude and phase change response caused by a corresponding system sensitivity to a particular forcing frequency. A resonance is typically identified by a substantial amplitude increase, and related phase shift.

**Rolling Element Bearing**. Bearing whose low friction qualities derive from rolling elements (balls or rollers), with little lubrication.

**Root Mean Square (rms)**. Square root of the arithmetical average of a set of squared instantaneous values. DSAs perform rms averaging digitally on successive vibration spectra.

**Rotor, Flexible**. A rotor which operates close enough to, or beyond its first bending critical speed for dynamic effects to influence rotor deformations. Rotors which cannot be classified as rigid rotors are considered to be flexible rotors.

**Rotor, Rigid**. A rotor which operates substantially below its first bending critical speed. A rigid rotor can be brought into, and will remain in, a state of satisfactory balance at all operating speeds when balanced on any two arbitrarily selected correction planes.

**RPM Spectral Map**. A spectral map of vibration spectra versus rpm.

**Runout Compensation**. Electronic correction of a transducer output signal for the error resulting from slow roll runout.

# S

**Seismic**. Refers to an inertially referenced measurement or a measurement relative to free space.

**Seismic Transducer**. A transducer that is mounted on the case or housing of a machine and measures casing vibration relative to free space. Accelerometers and velocity transducers are seismic.

**Signal Conditioner**. A device placed between a signal source and a readout instrument to change the signal. Examples: attenuators, preamplifiers, charge amplifiers.

**Signature**. Term usually applied to the vibration frequency spectrum which is distinctive and special to a machine or component, system or subsystem at a specific point in time, under specific machine operating conditions, etc. Used for historical comparison of mechanical condition over the operating life of the machine.

**Slow Roll Speed**. Low rotative speed at which dynamic motion effects from forces such as imbalance are negligible.

**Spectral Map**. A three-dimensional plot of the vibration amplitude spectrum versus another variable, usually time or rpm.

**Spectrum Analyzer**. An instrument which displays the frequency spectrum of an input signal.

**Stiffness**. The spring-like quality of mechanical and hydraulic elements to elasticity deform under load.

**Strain**. The physical deformation, deflection, or change in length resulting from stress (force per unit area).

**Subharmonic**. Sinusoidal quantity of a frequency that is an integral submultiple of a fundamental frequency.

**Subsynchronous**. Component(s) of a vibration signal which has a frequency less than shaft rotative frequency.

**Synchronous Sampling**. In a DSA, it refers to the control of the effective sampling rate of data; which includes the processes of external sampling and computed resampling used in order tracking.

# T

**Time Averaging**. In a DSA, averaging of time records that results in reduction of asynchronous components.

**Time Record**. In a DSA, the sampled time data converted to the frequency domain by the FFT. Most DSAs use a time record of 1024 samples.

**Torsional Vibration**. Amplitude modulation of torque measured in degrees peak-to-peak referenced to the axis of shaft rotation.

**Tracking Filter**. A low-pass or band-pass filter which automatically tracks the input signal. A tracking filter is usually required for aliasing protection when data sampling is controlled externally.

**Transducer**. A device for translating the magnitude of one quantity into another quantity.

**Transient Vibration**. Temporarily sustained vibration of a mechanical system. It may consist of forced or free vibration or both. Typically this is associated with changes in machine operating condition such as speed, load, etc.

**Transverse Sensitivity**. See Cross-Axis Sensitivity.

**Trigger**. Any event which can be used as a timing reference. In a DSA, a trigger can be used to initiate a measurement.

# U

**Unbalance**. See Imbalance.

**Uniform Window**. In a DSA, a window function with uniform weighting across the time record. This window does not protect against leakage, and should be used only with transient signals contained completely within the time record.

# V

**Vector**. A quantity which has both magnitude and direction (phase).

# W – Z

**Waterfall Plot**. See Spectral Map.

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